Geophysical Research Abstracts
Vol. 19, EGU2017-8963, 2017
EGU General Assembly 2017

3D stratigraphic modeling of the Congo turbidite system since 210 ka: an investigation of factors controlling sedimentation

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The geometry and internal functioning of turbidite systems are relatively well-constrained today. However, the respective role of autogenic (topographic compensation, dynamics of turbidity currents…) and allogenic factors (tectonics, sea-level, climate) governing their architectural evolution is still under debate.
The geometry of the Quaternary Congo Fan is characterized by successive sedimentary prograding/retrograding cycles bounded by upfan avulsions, reflecting a periodic control of sedimentation (Picot et al., 2016). Multi-proxy studies revealed a strong interplay between autogenic control and climate forcing as evidenced by changes in fluvial sediment supplies consistent with arid and humid periods in the Congo River Basin.

In the light of these results, the aim of this study is to investigate the relative impact of internal and external forcing factors controlling, both in time and space, the formation and evolution of depocenters of the Congo Deep-Sea Fan since 210 ka. This work represents the first attempt to model in 3D the stratigraphic architecture of the Congo turbidite system using DionisosFlow (IFP-EN), a diffusion process-based software. It allows the simulation of sediment transport and the 3D geometry reproduction of sedimentary units based on physical processes such as sea level changes, tectonics, sediment supply and transport.

According to the modeling results, the role of topographic compensation in the deep-sea fan geometry is secondary compared to climate changes in the drainage basin. It appears that a periodic variation of sediment discharge and water flow is necessary to simulate the timing and volume of prograding/retrograding sedimentary cycles and more particularly the upfan avulsion events. The best-fit simulations show that the overriding factor for such changes corresponds to the expansion of the vegetation cover in the catchment basin associated to the Milankovitch cycle of precession which controlled the West African Monsoon intensity. These external forcing factors are responsible for the evolution of the capacity of turbidity currents by directly acting on the river runoff magnitude and the sediment budget according to the balance between mechanical and chemical erosion. If the sediment supply is the key parameter for the large scale sedimentary cycles, a steep increase of the sand/mud ratio leads to the development of sub-cycles characterized by middle fan avulsions. We identified these events as related to abrupt destabilizations of river mouth bars linked to periodic Congo River floods. Finally, the local slope gradient only plays a role in the maximal length of the turbidity currents and deposition in the most distal part of the basin.

To conclude, the stratigraphic modeling allows us to propose an evolutionary "source to sink" model of the Quaternary Congo Fan, emphasizing the interconnection through time between drainage basin responses to climate change and sedimentary transfers in the deep-water environment.

Picot, M. et al., 2016. Controls on turbidite sedimentation: Insights from a quantitative approach of submarine channel and lobe architecture (Late Quaternary Congo Fan). Marine and Petroleum Geology, 72, 423-446.

Keywords: Congo, sedimentary basin, Quaternary, turbidite system, sedimentary cycles, geophysical data, stratigraphic modeling, DionisosFlow